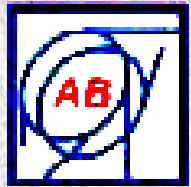


BEAM LOSS MONITORS DEPENDABILITY

STATE OF ART



Basic Concepts

System fault events

- * BLM are designed to prevent the Magnet Disruption (MaDi) due to an high loss (~ 30 downtime days).
- * BLM should avoid false dumps (FaDu) (~ 6 downtime hours).
- * Use of Safety Integrity Level (SIL), IEC 61508.



Sil Approach 1/4

Event likelihood (both)

Category	Description	Indicative frequency level (per year)
Frequent	Events which are very likely to occur	> 1
Probable	Events that are likely to occur	$10^{-1} - 1$
Occasional	Events which are possible and expected to occur	$10^{-2} - 10^{-1}$
Remote	Events which are possible but not expected to occur	$10^{-3} - 10^{-2}$
Improbable	Events which are unlikely to occur	$10^{-4} - 10^{-3}$
Negligible / Not credible	Events which are extremely unlikely to occur	$< 10^{-4}$

MaDi: 100 destructive losses/year



Sil Approach 2/4

Consequences

Category	Injury to personnel		Damage to equipment	
	Criteria	N. fatalities (indicative)	CHF Loss	Downtime
Catastrophic	Events capable of resulting in one or more fatalities	≥1	> 5*10 ⁷	> 6 months
Major	Events capable of resulting in very serious injuries	0.1 (or 1 over 10 accidents)	10 ⁶ – 5*10 ⁷	20 days to 6 months
Severe	Events which may lead to serious injuries	0.01 (or 1 over 100 accidents)	10 ⁵ – 10 ⁶	3 to 20 days
Minor	Events which may lead to minor injuries	0.001 (or 1 over 1000 accidents)	0 – 10 ⁵	< 3 days

MaDi

FaDu



Sil Approach 3/4

SILs

Event Likelihood	<u>MaDi</u> Consequence <u>FaDu</u>			
	Catastrophic	Major	Severe	Minor
Frequent	SIL 4	SIL 3	SIL 3	SIL 2
Probable	SIL 3	SIL 3	SIL 3	SIL 2
Occasional	SIL 3	SIL 3	SIL 2	SIL 1
Remote	SIL 3	SIL 2	SIL 2	SIL 1
Improbable	SIL 3	SIL 2	SIL 1	SIL 1
Negligible / Not Credible	SIL 2	SIL 1	SIL 1	SIL 1



Sil Approach 4/4

Failure probability

Low demand
mode of
Operation
(<1 year)

SIL	Average probability of failure to perform its design function on demand (FPPD _{ave})
4	$10^{-5} < Pr < 10^{-4}$
3	$10^{-4} < Pr < 10^{-3}$
2	$10^{-3} < Pr < 10^{-2}$
1	$10^{-2} < Pr < 10^{-1}$

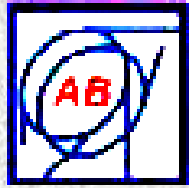
High demand /
continuous
mode of
operation

SIL	Probability of a dangerous failure per hour
4	$10^{-9} < Pr < 10^{-8}$
3	$10^{-8} < Pr < 10^{-7}$
2	$10^{-7} < Pr < 10^{-6}$
1	$10^{-6} < Pr < 10^{-5}$

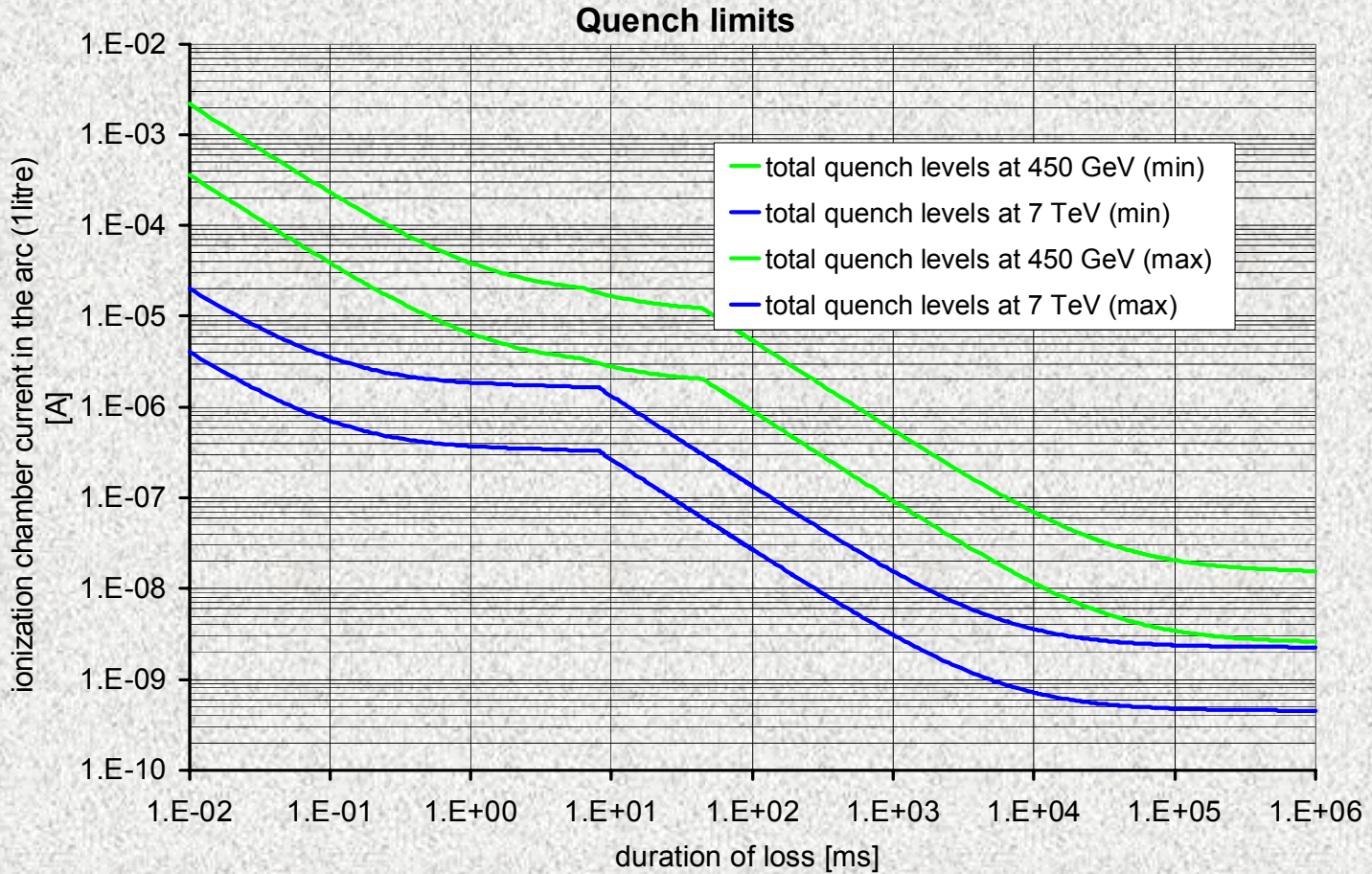


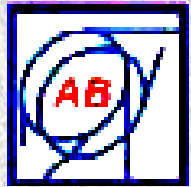
Our Scenario

- * ~180 BLMs for collimators.
- * ~3000 BLMs for magnets.
- * Scan every 40 μ s.
- * Check every 1 ms.
- * Signal with 8 order of magnitude.



Threshold Levels



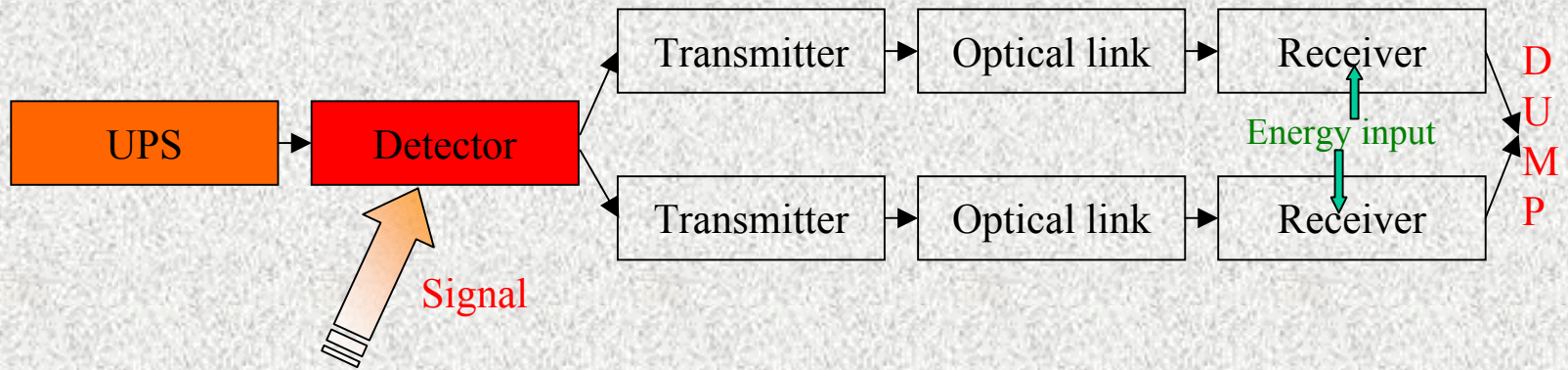


Our Selection

- * Ionization chambers: reliable (no fails with 200 chamber during 20 years in SPS), wide range.
- * Current to Frequent Converter (CFC), from 10^{-2} to $5 \cdot 10^6$ Hz.
- * Two optical lines: bandwidth, reliability.
- * Use FPGAs: reliability, flexibility, cheap.



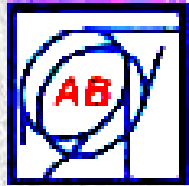
Our Layout



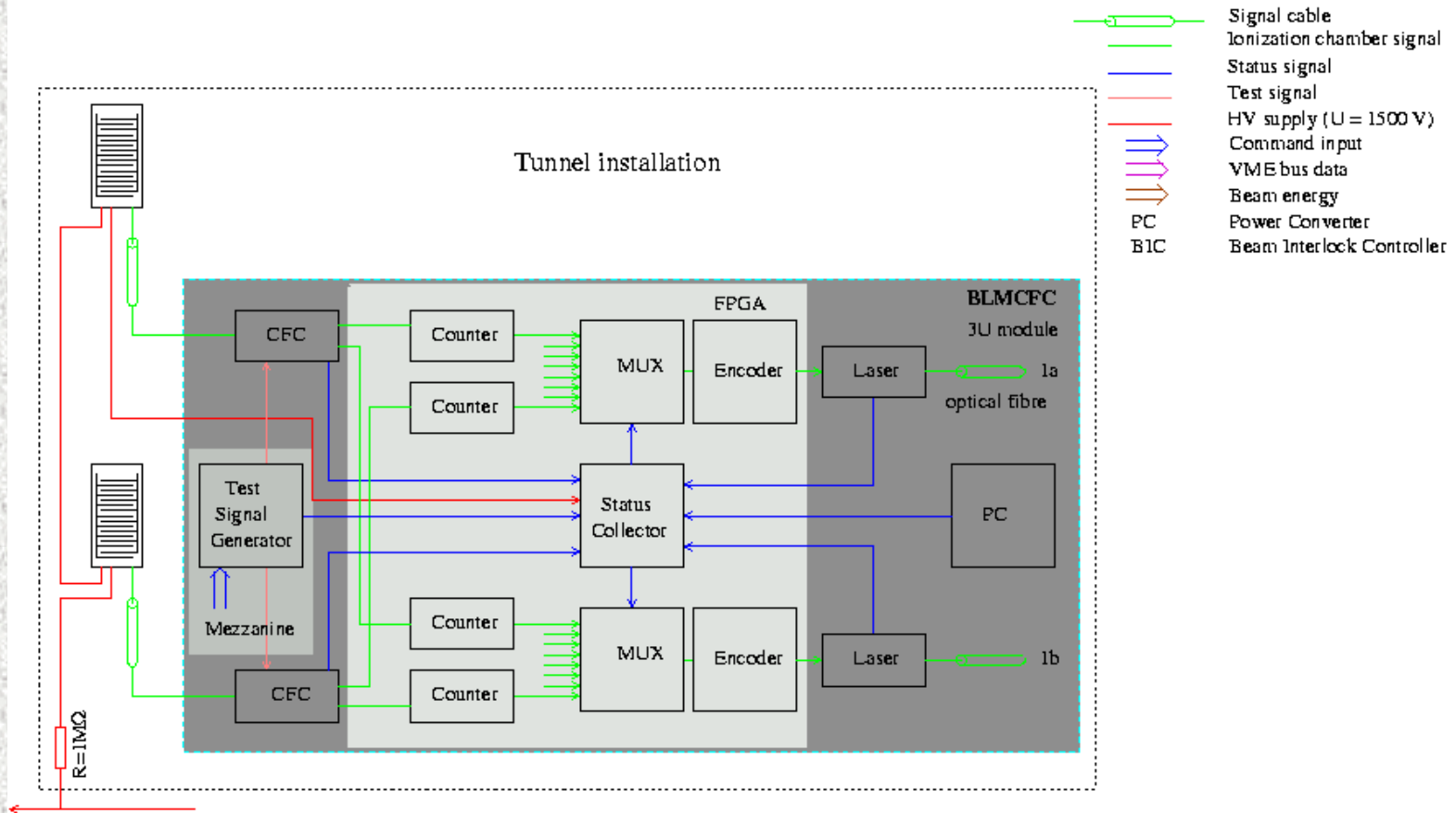
ELEMENT	λ [1/h]	inspection [h]
Ionization Chamber + 400m cable	2.58E-08	20
Amplifier (CFC)	2.78E-08	20
Photodiode	3.18E-08	2.78E-07
Switch (CFC)	8.70E-08	20
2 Optical connectors	2.00E-07	2.78E-07
Optical fiber	2.00E-07	2.78E-07
FPGA RX	6.99E-07	2.78E-07
UPS ??	1.00E-06	2.78E-07
FPGA TX	2.02E-06	2.78E-07
Laser	8.46E-06	2.78E-07

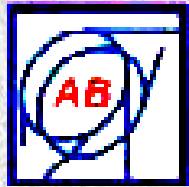


Front-end Electronic

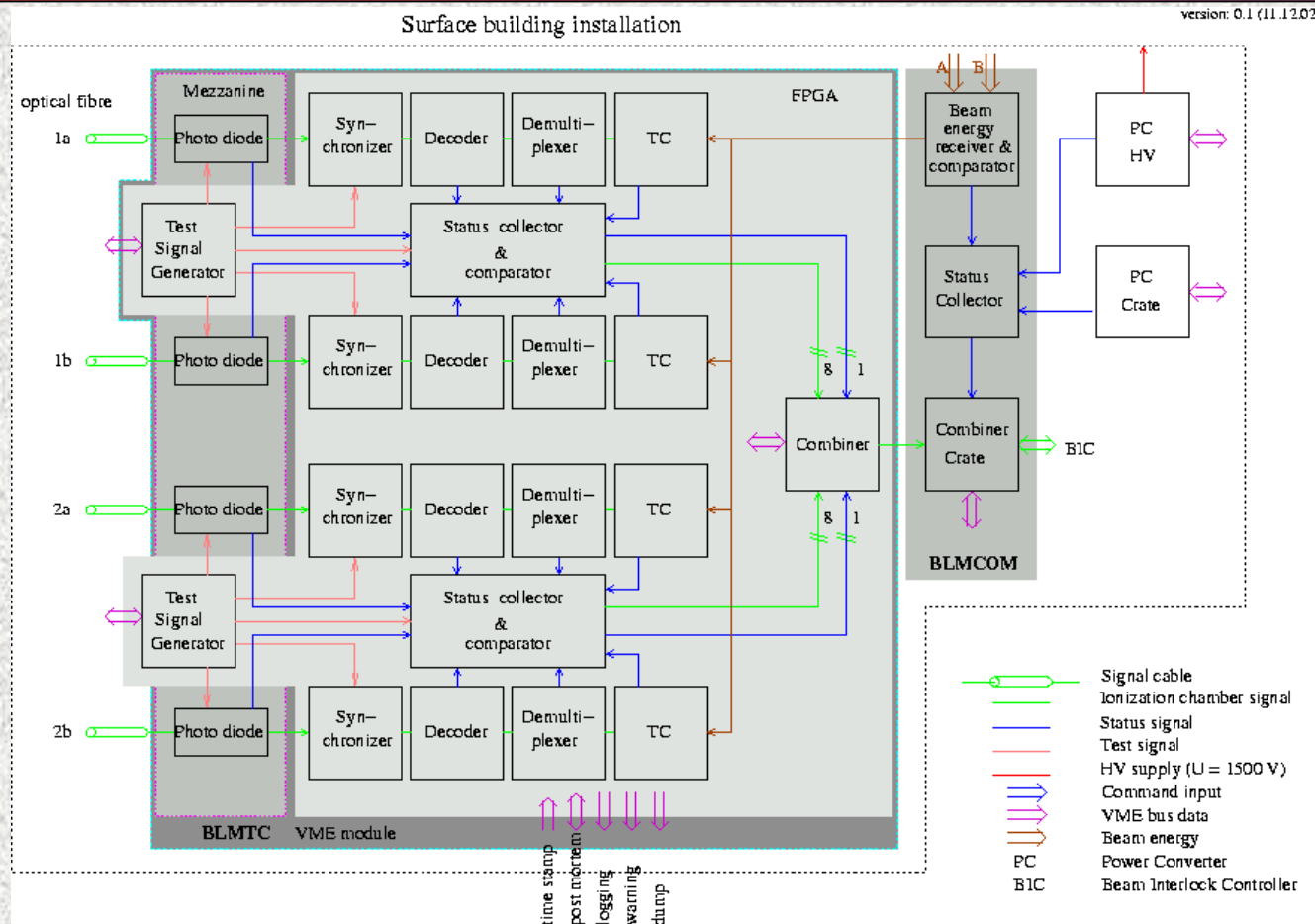


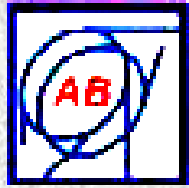
version: 0-4 (10.02.03)



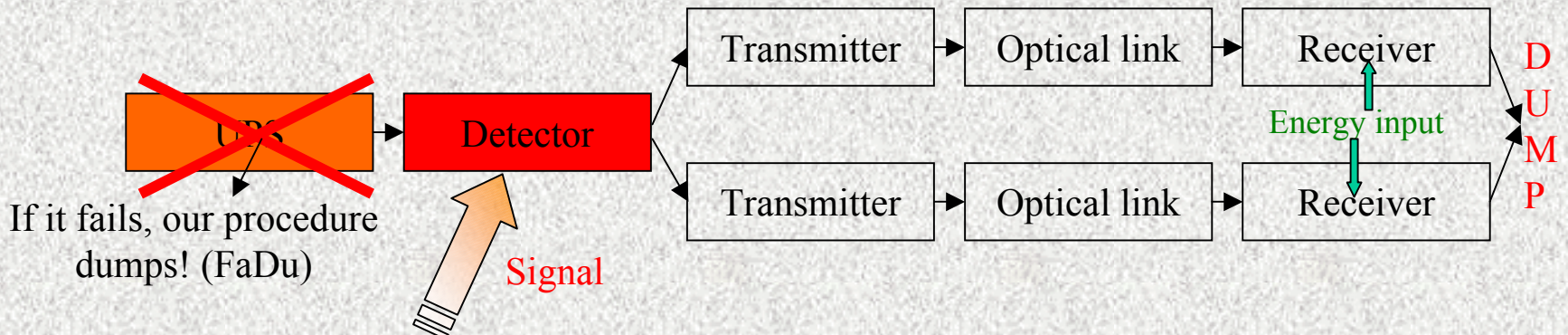


Back-end Electronic





MaDi 1/2



If it fails, our procedure dumps! (FaDu)

$$P_{\text{MaDi}} \sim P_S + Q_{\text{BLM}} + P_{\text{en-}} + Q_{\text{DUMP}}$$

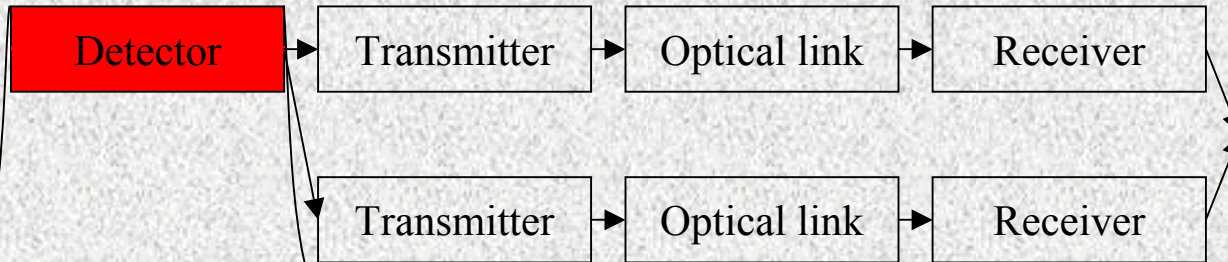
Probability to have a Magnet Disruption
 Probability not to detect the dangerous loss
 Unavailability of the BLM system
 Probability to underestimate the beam energy
 Unavailability of the DUMP system

$< 10^{-7} / \text{h}$
 $1.7 \cdot 10^{-6} / \text{h}$
 ?
 ?

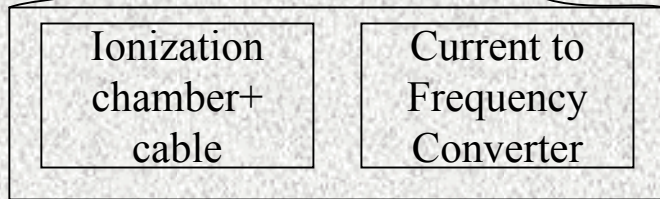
Threshold levels (FaDu)



MaDi 2/2

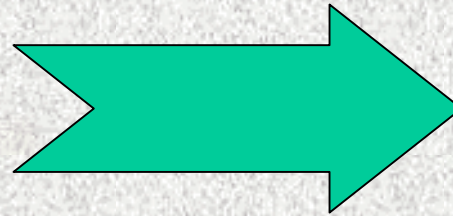


$7.0 \cdot 10^{-11}/h$

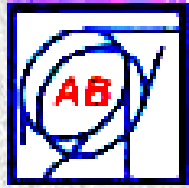


$< 2.8 \cdot 10^{-7}/h$ $1.4 \cdot 10^{-6}/h$

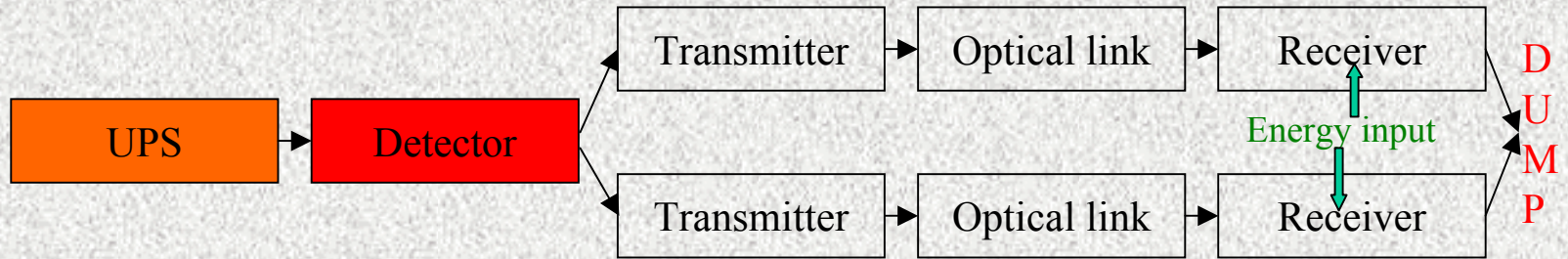
$Q_{BLM} = 1.7 \cdot 10^{-6}/h$



IMPROVE
ELECTRONIC
QUALITY +
TESTING IC



FaDu



$$P_{FaDu} \sim (P_{THR} + Q_{BLM} + P_{en+}) * 3200$$

Probability to
have a False
Dump

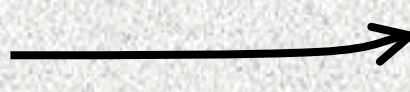
Probability to
have a false
dump signal

Unavailability
of the BLM
system+UPS

Probability to
overestimate
the beam
energy

Number of
channels

$< 10^{-6}/h$



$< 3 * 10^{-10} /h$



?

$2.7 * 10^{-6}/h$

?



Risk Matrix 1/2

* (Raw) Foreseen failure rate:

$$\square \text{MaDi: } 1.7 \cdot 10^{-6}/\text{h} * 4000 \text{ h/y} * 100 = 0.7/\text{y}$$

Probable

Beam hours: 200 d*20 h/d

Dangerous losses
per years

$$\square \text{FaDu: } 2.7 \cdot 10^{-6}/\text{h} * 4000 \text{ h/y} * 3200 = 35/\text{y}$$

Frequent

Number of
channels

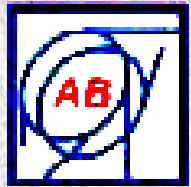


Risk Matrix 2/2

Frequency	Consequence			
	Catastrophic	<u>MaDi</u> Major	Severe	<u>FaDu</u> Minor
Frequent	I	I	I	II
Probable	I	I	II	III
Occasional	I	II	III	III
Remote	II	II	II	III
Improbable	II	III	III	IV
Negligible / Not Credible	III	IV	IV	IV

We are beyond the border !!

- I. Intolerable.
- II. Tolerable if risk reduction is impracticable or if costs are disproportionate.
- III. Tolerable if risk reduction cost exceeds improvement.
- IV. Acceptable.



Actions

1. Improve the Current to Frequency Converter electronic quality.
2. Procedure to test the Ionization Chamber as frequent as possible.
3. Collect data about current unavailability of Beam Energy System and Beam Interlock Controller.
4. Estimation of the threshold levels failure rate for FaDu.
5. Multiple detections? If yes: coincidence (es: 2001000) in the Beam Interlock Controller?